UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER II
SESSION 2016/2017

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COURSE NAME	:	ENGINEERING ELECTROMAGNETICS
COURSE CODE	:	BEF 22903
PROGRAMME CODE	:	BEV
EXAMINATION DATE	:	JUNE 2017
DURATION	:	3 HOURS
INSTRUCTION	:	ANSWER **ALL** QUESTIONS

THIS QUESTION PAPER CONSISTS OF **NINE (9)** PAGES

Q1 (a) Describe Coulomb's law in detail with the appropriate mathematical expression.

(4 marks)

(b) Describe Gauss's law in detail with the appropriate mathematical expression.

(2 marks)

(c) Calculate the potential difference between potential at $P(-2, 5, 1)$ and $Q(-1, 1, 2)$ if three point charges $Q_1 = 1\ \mu\text{C}$, $Q_2 = -2\ \mu\text{C}$, and $Q_3 = 3\ \mu\text{C}$ are located at (3, −4, 6), (1, 2, 3), and (0, 0, 4), respectively.

(10 marks)

(d) Formulate the electric field intensity, $\boldsymbol{E}$ due to the potential given as follows:

$$V = 2(x + y^2 + z^3)^{\frac{1}{2}}$$

(4 marks)

Q2 (a) Show that the total work required to position three point charge Q_1, Q_2, and Q_3 from infinity into an initially empty space is given by:

(6 marks)

$$W_T = \frac{1}{2}\sum_{k=1}^{3} Q_k V_k$$

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(b) Region 1 ($z < 0$) contains of neoprene dielectric material with $\varepsilon_r = 6.7$, while region 2 ($z > 0$) contains of graphite with $\varepsilon_r = 15$. The electric field intensity in region 2, $\boldsymbol{E}_2$ is given by:

$$\boldsymbol{E}_2 = -30\mathbf{a}_x - 10\mathbf{a}_y - 20\mathbf{a}_z \text{ V/m}$$

(i) Calculate the electric field density in region 1, $\boldsymbol{D}_1$.

(12 marks)

(ii) Evaluate the angle between $\boldsymbol{E}_1$ and the normal to the surface.

(3 marks)

Q3 (a) List **two (2)** types of current density ***J***.

(2 marks)

(b) A hollow cylinder of length 2 m has its cross sectional with inner radius of 2.5 cm and outer radius of 5.3 cm. The cylinder is made of carbon with $\sigma = 10^5$ mho/m. Determine the resistance between the end of cylinder.

(4 marks)

(c) The potential field $V = 3x^2y^3z - yz^2$ exist in a carbon disulfide material with $\varepsilon_r = 2.6$.

(i) Prove that V does not satisfy Laplace 's equation.

(8 marks)

(ii) Calculate the total charge if x, y, and z are within 0 and 2 m, respectively.

(6 marks)

Q4 (a) (i) List **two (2)** typical examples of inductor.

(2 marks)

(ii) Explain the **five (5)** steps procedure to determine the resistance, R of a given conducting material.

(5 marks)

(b) In the magnetic circuit of **Figure Q4(b)**, calculate the magnetic flux density in the air gap if the current in the coil is 40 A. Assume that the core is made of carbon steel with $\mu_r = 100$ and all branches have the same cross-sectional area of 20 cm^2.

(13 marks)

Q5 (a) State Faraday's law.

(2 marks)

(b) Consider the loop of the **Figure Q5(b)**. If $\boldsymbol{B} = \frac{\pi}{2}\mathbf{a}_z$ Wb/m^2, $R = 15\ \Omega$, $l = 12.5$ cm and the rod is moving with a constant velocity of $7\mathbf{a}_x$ m/s:

(i) Determine the induced emf in the rod.

(2 marks)

(ii) Determine the current through the resistor.

(2 marks)

(iii) Determine the power dissipated by the resistor.

(2 marks)

(c) A conductor bar can slide freely over two conducting rails as shown in **Figure Q5(c).** Calculate the induced voltage in the bar:

(i) If the bar is stationed at $y = 6$ cm and $\boldsymbol{B} = 2.4\cos 10^6 t\, \mathbf{a}_z$ mWb/m^2.

(3 marks)

(ii) If the bar slides at a velocity of $\boldsymbol{u} = 12\mathbf{a}_y$ m/s and $\boldsymbol{B} = 5.3\mathbf{a}_z$ mWb/m^2.

(3 marks)

(iii) If the bar slides at a velocity of $\boldsymbol{u} = 21\mathbf{a}_y$ m/s and $\boldsymbol{B} = 5\cos(10^6 t - y)$ mWb/m^2.

(6 marks)

-END OF QUESTIONS-

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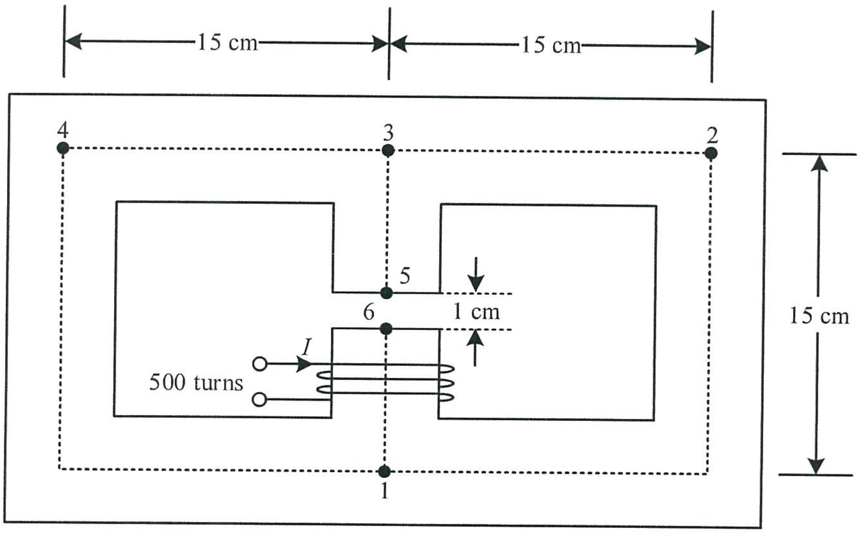

Figure Q4(b)

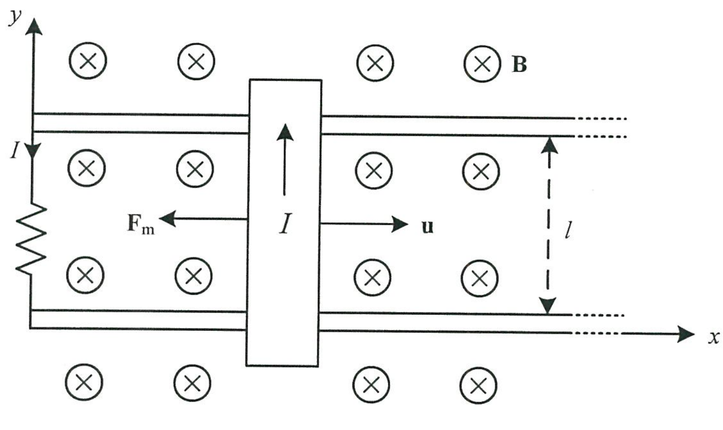

Figure Q5(b)

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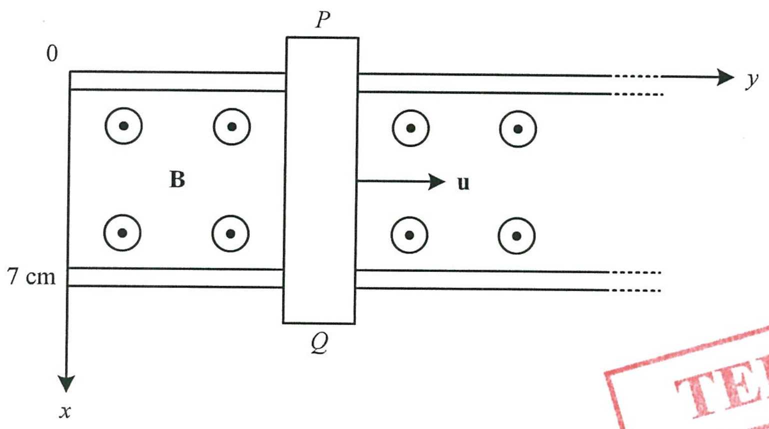

Figure Q5(c)

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Appendix 1

Operation	Cylindrical coordinates (ρ, φ, z)
A vector field $\mathbf{A}$	$A_\rho \hat{\boldsymbol{\rho}} + A_\varphi \hat{\boldsymbol{\varphi}} + A_z \hat{\mathbf{z}}$
Gradient ∇f	$\frac{\partial f}{\partial \rho}\hat{\boldsymbol{\rho}} + \frac{1}{\rho}\frac{\partial f}{\partial \varphi}\hat{\boldsymbol{\varphi}} + \frac{\partial f}{\partial z}\hat{\mathbf{z}}$
Divergence $\nabla \cdot \mathbf{A}$	$\frac{1}{\rho}\frac{\partial(\rho A_\rho)}{\partial \rho} + \frac{1}{\rho}\frac{\partial A_\varphi}{\partial \varphi} + \frac{\partial A_z}{\partial z}$
Curl $\nabla \times \mathbf{A}$	$\left(\frac{1}{\rho}\frac{\partial A_z}{\partial \varphi} - \frac{\partial A_\varphi}{\partial z}\right)\hat{\boldsymbol{\rho}} + \left(\frac{\partial A_\rho}{\partial z} - \frac{\partial A_z}{\partial \rho}\right)\hat{\boldsymbol{\varphi}} + \frac{1}{\rho}\left(\frac{\partial(\rho A_\varphi)}{\partial \rho} - \frac{\partial A_\rho}{\partial \varphi}\right)\hat{\mathbf{z}}$
Laplace operator $\nabla^2 f \equiv \Delta f$	$\frac{1}{\rho}\frac{\partial}{\partial \rho}\left(\rho\frac{\partial f}{\partial \rho}\right) + \frac{1}{\rho^2}\frac{\partial^2 f}{\partial \varphi^2} + \frac{\partial^2 f}{\partial z^2}$

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Operation	Spherical coordinates (r, θ, φ), where θ is the polar angle and φ is azimuthal
A vector field $\mathbf{A}$	$A_r \hat{\mathbf{r}} + A_\theta \hat{\boldsymbol{\theta}} + A_\varphi \hat{\boldsymbol{\varphi}}$
Gradient ∇f	$\frac{\partial f}{\partial r}\hat{\mathbf{r}} + \frac{1}{r}\frac{\partial f}{\partial \theta}\hat{\boldsymbol{\theta}} + \frac{1}{r\sin\theta}\frac{\partial f}{\partial \varphi}\hat{\boldsymbol{\varphi}}$
Divergence $\nabla \cdot \mathbf{A}$	$\frac{1}{r^2}\frac{\partial(r^2 A_r)}{\partial r} + \frac{1}{r\sin\theta}\frac{\partial}{\partial \theta}(A_\theta \sin\theta) + \frac{1}{r\sin\theta}\frac{\partial A_\varphi}{\partial \varphi}$
Curl $\nabla \times \mathbf{A}$	$\frac{1}{r\sin\theta}\left(\frac{\partial}{\partial \theta}(A_\varphi \sin\theta) - \frac{\partial A_\theta}{\partial \varphi}\right)\hat{\mathbf{r}} + \frac{1}{r}\left(\frac{1}{\sin\theta}\frac{\partial A_r}{\partial \varphi} - \frac{\partial}{\partial r}(rA_\varphi)\right)\hat{\boldsymbol{\theta}} + \frac{1}{r}\left(\frac{\partial}{\partial r}(rA_\theta) - \frac{\partial A_r}{\partial \theta}\right)\hat{\boldsymbol{\varphi}}$
Laplace operator $\nabla^2 f \equiv \Delta f$	$\frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2\frac{\partial f}{\partial r}\right) + \frac{1}{r^2\sin\theta}\frac{\partial}{\partial \theta}\left(\sin\theta\frac{\partial f}{\partial \theta}\right) + \frac{1}{r^2\sin^2\theta}\frac{\partial^2 f}{\partial \varphi^2}$

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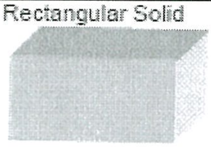
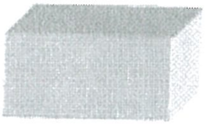
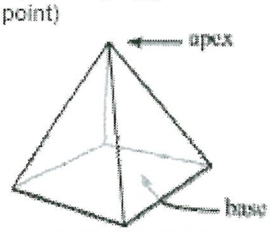
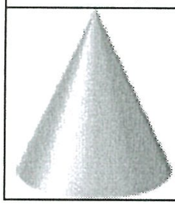
Appendix 2

Figure	*Volume*	*Surface Area*
Sphere 	$V = \frac{4}{3}\pi r^3$, r radius	$S = 4\pi r^2$, r radius
Cube 	$V = s^3$, s side	$S = 6s^2$, s side
Rectangular Solid 	$V = A^2 h$, A^2 is area of the base, h height. $V = lwh$, l length, w width, h height.	$S = 2lw + 2lh + 2wh$ $= 2(lw + lh + wh)$ l length, w width, h height.
Cylinder 	$V = \pi r^2 h$, r radius, h height	$S = \underbrace{2\pi r^2}_{\text{top \& bottom}} + \underbrace{2\pi rh}_{\text{lateral side}}$
Prisms: Parallel flat polygon top and bottom (bases). 	$V = A^2 h$, A^2 is area of the base, h height.	Calculus topic – to come
Pyrimids (polygon base to a point) 	$V = \frac{1}{3}Ah$, A is area of the base, h height.	Calculus topic – to come
	$V = \frac{1}{3}\pi r^2 h$, r is the radius of the circular base, h height	$S_{total} = \underbrace{\pi r^2}_{\text{base area}} + \underbrace{\pi r\sqrt{r^2 + h^2}}_{\text{lateral area}}$, $\sqrt{r^2 + h^2}$ is slant height

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Appendix 3

- **Reciprocal identities**

$$\sin u = \frac{1}{\csc u} \quad \cos u = \frac{1}{\sec u}$$
$$\tan u = \frac{1}{\cot u} \quad \cot u = \frac{1}{\tan u}$$
$$\csc u = \frac{1}{\sin u} \quad \sec u = \frac{1}{\cos u}$$

- **Pythagorean Identities**

$$\sin^2 u + \cos^2 u = 1$$
$$1 + \tan^2 u = \sec^2 u$$
$$1 + \cot^2 u = \csc^2 u$$

- **Quotient Identities**

$$\tan u = \frac{\sin u}{\cos u} \quad \cot u = \frac{\cos u}{\sin u}$$

- **Co-Function Identities**

$$\sin(\frac{\pi}{2} - u) = \cos u \quad \cos(\frac{\pi}{2} - u) = \sin u$$
$$\tan(\frac{\pi}{2} - u) = \cot u \quad \cot(\frac{\pi}{2} - u) = \tan u$$
$$\csc(\frac{\pi}{2} - u) = \sec u \quad \sec(\frac{\pi}{2} - u) = \csc u$$

- **Parity Identities (Even & Odd)**

$$\sin(-u) = -\sin u \quad \cos(-u) = \cos u$$
$$\tan(-u) = -\tan u \quad \cot(-u) = -\cot u$$
$$\csc(-u) = -\csc u \quad \sec(-u) = \sec u$$

- **Sum & Difference Formulas**

$$\sin(u \pm v) = \sin u \cos v \pm \cos u \sin v$$
$$\cos(u \pm v) = \cos u \cos v \mp \sin u \sin v$$
$$\tan(u \pm v) = \frac{\tan u \pm \tan v}{1 \mp \tan u \tan v}$$

- **Double Angle Formulas**

$$\sin(2u) = 2\sin u \cos u$$
$$\cos(2u) = \cos^2 u - \sin^2 u$$
$$= 2\cos^2 u - 1$$
$$= 1 - 2\sin^2 u$$
$$\tan(2u) = \frac{2\tan u}{1 - \tan^2 u}$$

- **Power-Reducing/Half Angle Formulas**

$$\sin^2 u = \frac{1 - \cos(2u)}{2}$$
$$\cos^2 u = \frac{1 + \cos(2u)}{2}$$
$$\tan^2 u = \frac{1 - \cos(2u)}{1 + \cos(2u)}$$

- **Sum-to-Product Formulas**

$$\sin u + \sin v = 2\sin\left(\frac{u+v}{2}\right)\cos\left(\frac{u-v}{2}\right)$$
$$\sin u - \sin v = 2\cos\left(\frac{u+v}{2}\right)\sin\left(\frac{u-v}{2}\right)$$
$$\cos u + \cos v = 2\cos\left(\frac{u+v}{2}\right)\cos\left(\frac{u-v}{2}\right)$$
$$\cos u - \cos v = -2\sin\left(\frac{u+v}{2}\right)\sin\left(\frac{u-v}{2}\right)$$

- **Product-to-Sum Formulas**

$$\sin u \sin v = \frac{1}{2}[\cos(u-v) - \cos(u+v)]$$
$$\cos u \cos v = \frac{1}{2}[\cos(u-v) + \cos(u+v)]$$
$$\sin u \cos v = \frac{1}{2}[\sin(u+v) + \sin(u-v)]$$
$$\cos u \sin v = \frac{1}{2}[\sin(u+v) - \sin(u-v)]$$

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